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# Prospects for Real-Time Management of Water Quality in the San Joaquin River Basin, California

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**Earth Sciences Division**

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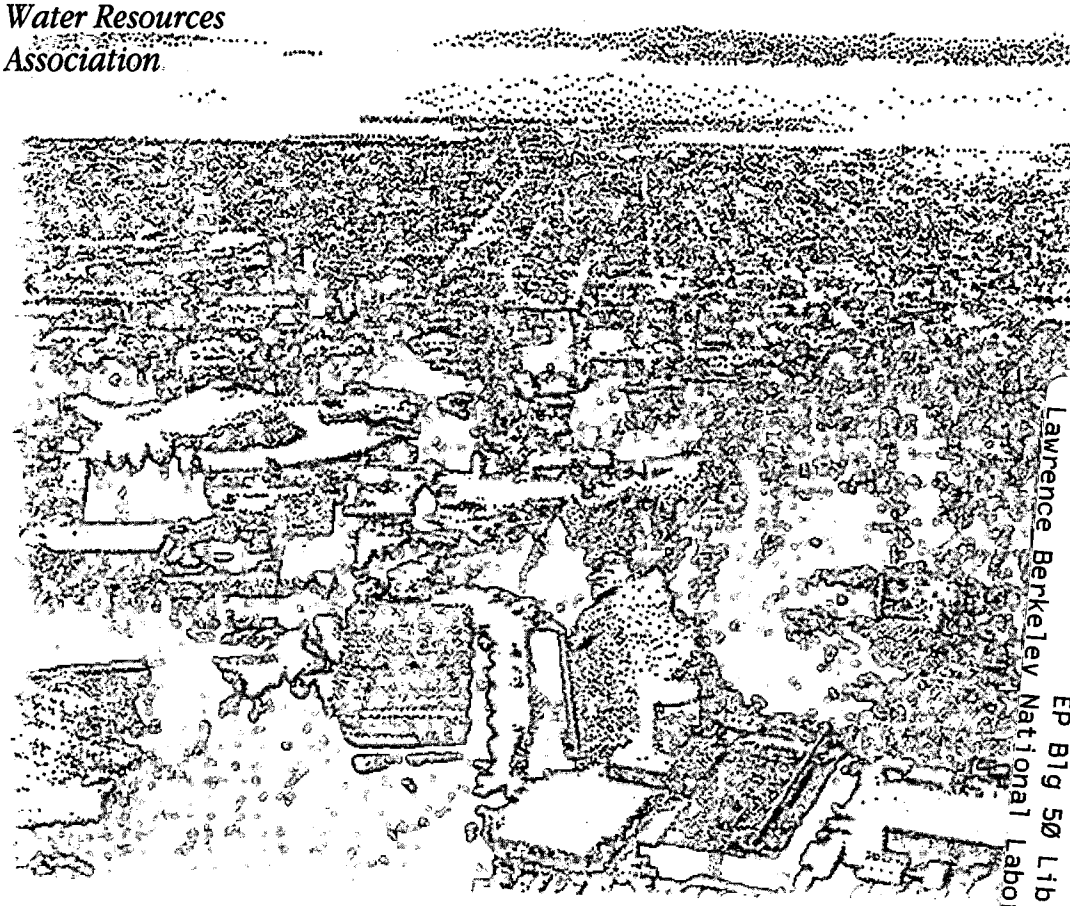

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# Prospects For Real-Time Management Of Water Quality In The San Joaquin River Basin, California

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# PROSPECTS FOR REAL-TIME MANAGEMENT OF WATER QUALITY IN THE SAN JOAQUIN RIVER BASIN, CALIFORNIA

N.W.T Quinn [1] and J.F. Karkoski [2]

## ABSTRACT

Implementation of a real-time water quality forecasting model to help improve the timing, coordination and management of saline agricultural and wetland drainage to meet water quality objectives in the San Joaquin River is discussed in this paper. The water quality forecasting model SJRIODAY and the graphical user interface, developed for the model to make the software accessible to a wide range of potential decision makers, is described. Weekly forecasts produced during the past fourteen months are compared to real-time flow and electrical conductivity data. A case study is also described in which wetland drainage releases were scheduled to coincide with a period of high river flows and significant river assimilative capacity for salt loads.

## INTRODUCTION

Real-time water quality management is a system of techniques that continuously update the state of knowledge of a system and allow actions to be taken to meet water quality objectives. Such a system is being developed in the San Joaquin River Basin of California to promote voluntary compliance with State water quality objectives for priority pollutants such as selenium, boron and TDS.

The techniques required to collect and transmit flow and stage data are well established. In California, state and federal agencies such as the

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the U.S. Geological Survey collect flow and stage data, routinely, for a Department of Water Resources (DWR), the U.S. Bureau of Reclamation (USBR) and variety of applications. Only the California Data Exchange Center (CDEC), a department within the DWR, provides river stage and flood warning information on a real time basis. The major clients of this system are local and state agencies concerned with flood management and the provision of emergency services. Agencies, such as the U.S. Army Corps of Engineers, also utilize this information to decide reservoir release schedules during high runoff periods. Another program, managed by the DWR, is the California Irrigation Management Information System (CIMIS) which provides daily weather and evapotranspiration data to help farmers make decisions related to crop planting and irrigation scheduling.

The real-time water quality management system under development for the San Joaquin River Basin takes advantage of some of the features of the existing hydrologic data acquisition and forecasting programs. Unique aspects of the real-time water quality management system that are not replicated by current programs are:

1) use of water quality sensors - currently only EC, temperature and pH from the extensive list of elements of concern within California's river systems can be continuously logged;
2) a continuous and integrated system of data error checking and validation since data is used for regulatory purposes;
3) addition of control systems that can be used to manage agricultural and wetland drainage water flow and water;
4) institutions that coordinate actions and responses of regulators; operators, public and private entities.

The evolution of a real-time water quality management system for the San Joaquin River basin will be examined in this paper.

## BACKGROUND

The San Joaquin River Basin drains an area of approximately 13,500 square miles. Runoff in the Basin is dominated by snowmelt and rainfall from the Sierra Nevada Range and its foothills on the east side of the Basin. The San Joaquin River and three tributaries on the east side of the Basin - the

Merced River, the Tuolumne River, and the Stanislaus River - provide most of the natural drainage to the Sacramento - San Joaquin Delta (Figure 1). The predominant land use in the San Joaquin River Basin is irrigated agriculture. An important source of irrigation water on the west side of the valley is imported water from the Sacramento-San Joaquin Delta. The east side tributaries and ground water provide the majority of the irrigation water supply to the east-side of the San Joaquin Valley.

The soils in the Grasslands basin are naturally high in salts and of low permeability. The low transmissivity of the soils combined with the importation of water has necessitated the installation of artificial drainage in low lying agricultural areas. Drainage produced from a 90,000-acre agricultural area in the southern part of the Grasslands Sub-basin (hereafter referred to as the Drainage Study Area - DSA) contains high concentrations of certain trace elements that are harmful to fish and wildlife, as well as soluble salts. The primary constituents of concern are salt,boron, and selenium.

In addition to discharges from the DSA, surrounding wetland areas also contribute a significant salt load to the San Joaquin River during the spring months (Grober, et al, 1995). The combined discharges from the agricultural lands and wetlands is conveyed through a system of canals and natural streams to the San Joaquin River. From Figure 2 it is apparent that the relative salt load contribution from the combined agricultural and wetland practices in the Grassland watershed is high, when compared to other sources of salt in the San Joaquin River Basin. Dilution of the poor quality discharges from the Grasslands watershed is provided by the east-side tributaries. Flows in the east-side tributaries are regulated to a large degree by upstream reservoirs which, in turn, are operated according to predetermined rules and release schedules. These rules and release schedules account for flood storage requirements, fish migration, irrigation demands, hydropower, water quality and recreation.

In contrast to the high degree of regulation and control of east - side tributary flows, the discharge of pollutants from the DSA has historically been unregulated and uncontrolled. Sump pumps associated with subsurface agricultural drainage systems are designed to turn on automatically when water reaches a set level in the sump. Hence, the pattern of discharges from agricultural lands generally mirrors the irrigation season. In contrast, surface drainage discharge from seasonal wetlands occurs in early spring between February to April. Some control of the scheduling of the seasonal

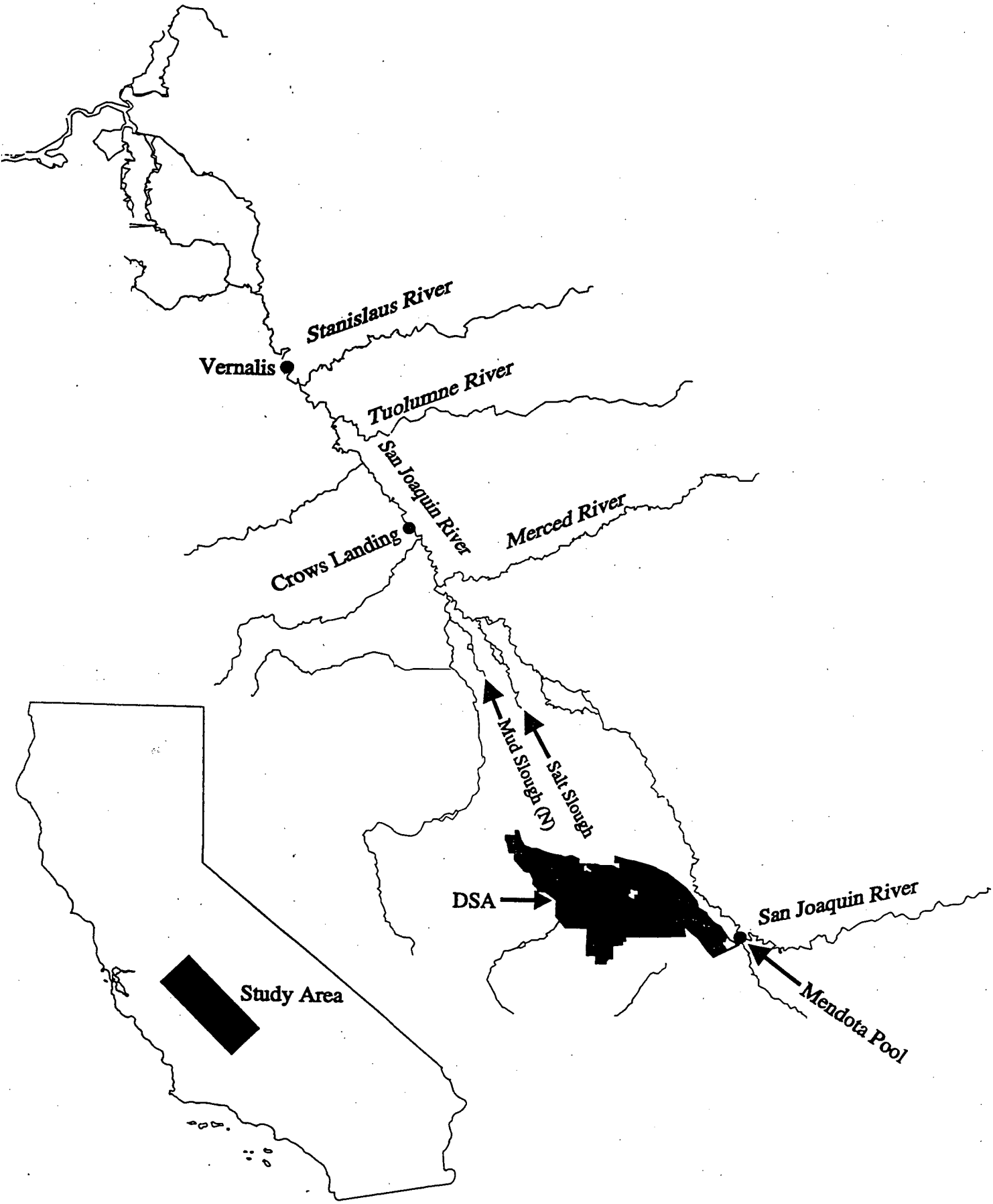


Figure 1. San Joaquin Basin and Grasslands Drainage Service Area showing major tributaries and drainage discharge points.

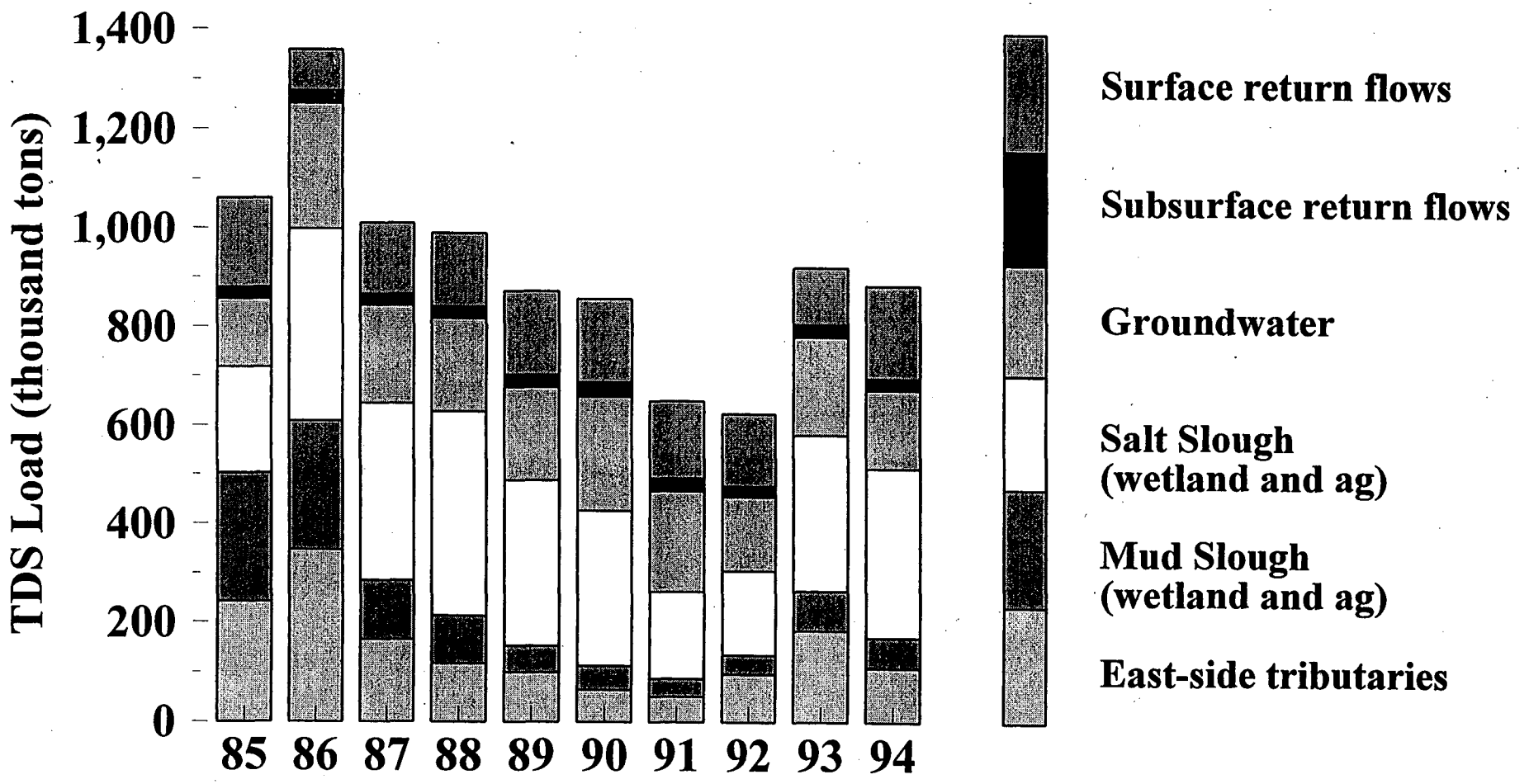


Figure 2. Contribution to salinity loading from various sources in the San Joaquin Basin.

wetland drainage can be exercised by wetland managers, although these schedules are determined to a large extent by habitat requirements and local management preferences of privately owned duck clubs.

The timing of the discharges of dissolved solids and trace elements from the DSA and the timing of reservoir releases is such that the assimilative capacity of the San Joaquin River is often exceeded at the compliance monitoring locations causing the water quality objectives to be violated. Opportunities for adjusting the timing of discharges and reservoir releases have been identified (Hildebrand, 1989) although the practical constraints to making such adjustments have not been thoroughly explored (Karkoski, et al, 1995). By making such adjustments, temporal variations in water quality could be minimized and the frequency of violation of water quality objectives could be reduced. A real-time water quality management system has the potential to allow continued discharge of salt from agricultural lands and wetlands while minimizing the impacts on the San Joaquin River and eliminating violations of water quality objectives.

## EVOLUTION OF REAL-TIME WATER QUALITY MODELING IN THE SAN JOAQUIN BASIN

Previous real-time water quality modeling efforts in the San Joaquin Basin have mostly focused on screening level assessments of operational constraints and opportunities to agricultural drainage discharge. The U.S. Bureau of Reclamation (USBR) developed a sophisticated planning model which considered the implementation of several alternatives to meet selenium and boron water quality objectives in the San Joaquin River (Quinn et al. 1993). The alternatives considered were irrigation improvements, drainage water reuse, land retirement, and the use of holding reservoirs to regulate the release of drainage to the River. These alternatives were optimized to minimize the size of the regulating reservoirs and to ensure that the constraining water quality objective (selenium or boron) was not exceeded. The agricultural area considered was restricted to those irrigation districts with Federal water supply contracts, which applied to approximately two-thirds of the DSA. The results of the modeling analysis suggested that with investments in drainage recycling facilities and the construction of regulating reservoirs with a total capacity of 3,450 acre-ft capacity distributed among four water districts (Panoche, Pacheco, Broadview and San Luis), water quality objectives

could be met at all times. The USBR model assumed perfect forecast and response to receiving water assimilative capacity and that the water quality of irrigation water supply and pumpage remained constant over the simulation period.

Another screening level model (Karkoski, 1995 unpublished analysis) considered the effects of load reductions and model and response errors on the sizing of regulating reservoirs. Model and response errors were expressed by allowing only 80% of the available assimilative capacity to be used. When evaporation effects are considered, the storage size required for regulating reservoirs was found to be 21,700 acre-ft. The large difference in regulating reservoir volume is a function of the different assumptions made in the two modeling approaches. Whereas in the USBR model the full assimilative capacity of the river was available and there was no annual selenium load cap imposed, the CRWQCB model assumed sub-optimal utilization of the available assimilative capacity and imposed the CRWQCB Basin Plan annual selenium discharge load cap of 8000 lbs. The CRWQCB model also assumed that a mean annual discharge of selenium from the agricultural water districts to the San Joaquin river of 6500 lbs.

These models were important in introducing the concept of real-time drainage management as a means of improving compliance with SWRCB water quality objectives and in establishing an initial database for future studies. These models were simplistic from an operational viewpoint however since they assumed a monthly decision time-step and ignored the inherent inflexibility of drainage management at the water district level. Although the second model recognized the difficulty of taking advantage of the full river assimilative capacity it did not recognize that operational flexibility varies throughout the year - hence a single value for percent use would not be realistic.

**Screening Models For River Assimilative Capacity**

Another approach to real-time water quality management was advanced that attempted to subsume historical drainage discharges in setting selenium load limits. Steady-state selenium effluent levels, adjusted for seasonal assimilative capacity variations, year type and a prescribed exceedence criterion, were set using a modified EPA load setting methodology. In order to ensure that selenium water quality objectives are not violated more frequently than allowed by federal regulation (once every three years), effluent limits were established based on low flow conditions. The selenium

load limits model was developed for the DSA based on a twenty-two year period of record. Since variations in the load limits were based on season and water year type - the effluent limits become quasi-steady state.

Table 1 compares the annual allowable selenium load for dry years and wet years using dynamic (real-time) versus quasi-steady state modeling assumptions. As can be seen in this table the advantages to the discharger of using a real-time system are significant with respect to the amount of selenium load that could be discharged. Hence it is to the long term benefit of the growers in the DSA to maximize their discharge of subsurface drainage in order to maintain a salt balance in the Basin.

Table 1. Comparison of real-time and quasi-static selenium load limits.

| | WET YEAR Se LOAD (lbs) | DRY YEAR Se LOAD (lbs) |
|---|---|---|
| QUASI-STATIC | 3090 | 1001 |
| DYNAMIC (REAL-TIME) | 7400 | 4630 |

**Operations Models**

Although the screening level models point to the potentially significant advantages of a real-time system, the actual opportunities presented by a real-time system can only be evaluated with the development of an operations model. An operations model is inherently more data intensive than a screening or planning model.

The literature contains many examples of water related problems that have been addressed fully or in part through real-time data acquisition, dissemination and operational control. Much of the literature is in the general field of optimization, dynamic programming and optimal control theory. The efforts of these researchers highlight some of the challenges and potential solutions in the development of a real time water quality management system for the San Joaquin River.

Krajewski, et al (1993) considered the real time optimal control of power plant cooling water discharges. The effect of a single major discharge (power plant cooling return flows) along with ambient hydrometeorological conditions was modelled to determine compliance with the temperature standard twelve

downstream. A thermal model was used to supply data to an optimization model which minimized the losses due to non-compliance (when the power plant was unable to produce at a potential level and penalties for violating the temperature standard. The loss function due to standard violations became stochastic in nature since it was dependent on the thermal model, which, itself, contained errors in model structure and model inputs (forecasted hydrometeorological conditions and initial and boundary conditions). Krajewski et al. (1993) were able to determine the effect of errors in forecasted hydrometeorogical conditions on model error and the calculated net benefit.

Novotny et al. (1992) investigated the challenges of adopting a real time control management scheme to wastewater treatment plants. Treatment plants are often designed based on steady state assumptions of influent to the treatment plant and allowable effluent from the plant. Novotny et al. (1992) suggested that a treatment process management scheme should be adaptive, predictive, and efficient. The system should be able to adapt to variations in input, able to forecast input changes, and be efficient by limiting idleness of plant units and the discharge of untreated waste. Storage was suggested as a buffer against temporal variations in assimilative capacity of the receiving water. Modelling requirements included an assessment of output to the environment, response of the environment to the output and optimization of the system to maximize efficiency.

Krajewski et al. (1993) demonstrated that model errors due to lack of information on hydrodynamic parameters (e.g. channel geometry), poorly understood processes (e.g. ground water inflow), and lack of input data (e.g. wetland and agricultural return flows) can have a significant impact on the benefits realized from a real time system. Novotny et al. (1992) suggested that a recursive parameter estimative method for autoregressive moving average models or a neural network model provides the desirable features of adaptability and predictability required for real time control of wastewater treatment processes. The need for these features is heightened when the size and variability of the system to be modelled increases - i.e. the forecast lead time and error increases.

Although the general problems of data reliability are common to most of the real-time applications discussed in the literature most appeared relatively tractable compared to the water quality management problem on the San Joaquin River. This can be illustrated by describing the path taken in developing the current water quality model for the San Joaquin River.

## REAL-TIME DATA ACQUISITION SYSTEM

Although river stage, EC and temperature have been monitored on a real-time basis, other real-time water quality monitoring is generally limited to those parameters such as dissolved oxygen for which no sample preparation is required. Techniques for the real time measurement of other parameters of interest in the San Joaquin River, such as selenium and boron, have not been established nor are reliable sensors available.

A real-time water quality monitoring network has been established in the Grassland Basin and the main stem of the San Joaquin River. Ten sites were chosen for real-time monitoring of flow, electrical conductivity and temperature along the San Joaquin River and its tributaries. These monitoring sites, with the data collected at each site are listed below:

Mud Slough within Kesterson Wildlife Refuge, near Gustine (EC,flow,temp)
Salt Slough at Highway 165 Bridge (EC,flow,temp)
Merced River near Stevinson (EC,flow, temp)
San Joaquin River at Crows Landing Bridge (EC,flow,temp)
San Joaquin River at Vernalis Bridge (EC,flow,temp)
Grasslands Bypass opposite Pond 7, Kesterson Reservoir (EC,flow,temp)
Orestimba Creek (EC,flow)
San Joaquin River at Newman bridge (flow)
San Joaquin River at Lander Avenue Bridge (EC,flow temp)
Patterson ID diversion from San Joaquin River (flow)
West Stanislaus ID diversion from San Joaquin River (flow).

The locations of these stations are shown in Figure 3. The data from these stations is currently telemetered via modem to central data processing station in the USBR and the DWR, where the information is checked for errors and missing values, and parsed into a format such that it can be accessed by a daily water quality forecasting model. The evolution of this model and its application is the nexus of water resources modeling activities in four agencies within California: the State Water Resources Control Board, the US Bureau of Reclamation, the California Department of Water Resources and the California Regional Water Quality Control Board.

# Lower San Joaquin River Monitoring Network

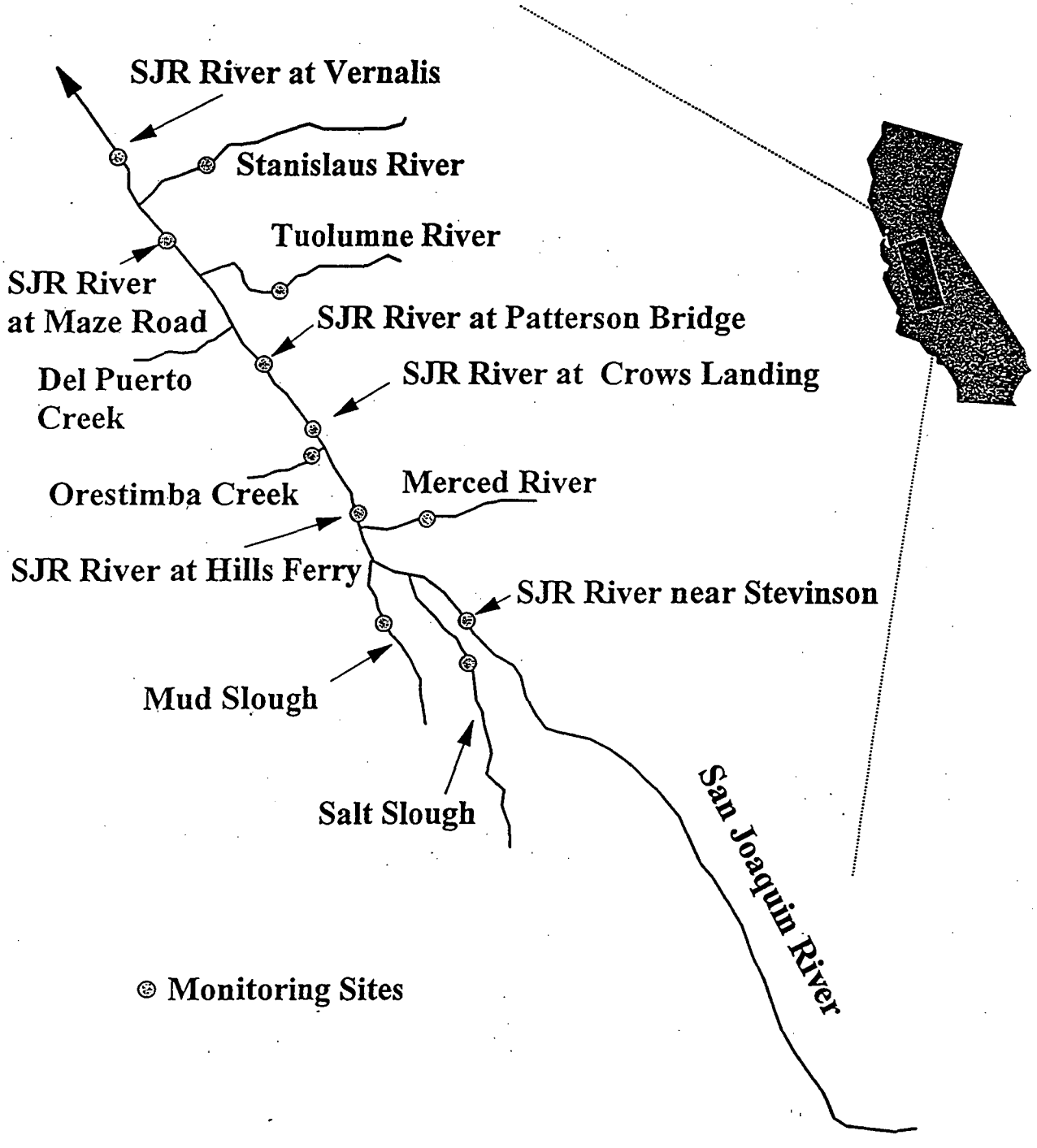


Figure 3. Location of real-time flow water quality monitoring sites in the San Joaquin Basin.

## SAN JOAQUIN RIVER DAILY INPUT-OUTPUT MODEL

The San Joaquin River Daily Input-Output model is a mass balance model which calculates daily flows and concentrations of total dissolved solids (TDS), boron, and selenium for a 60 mile reach of the San Joaquin River from Lander Avenue to Vernalis (SWRCB 1985). An extensive database was assembled, with data for water years 1977 to 1985, to run the model. The SJRIO was modified to accept stochastic data so that it could be run with historical data, stochastic data or a combination of both. The model has been further modified to run on a daily time step so that it can be used with real time flow and water quality data on the SJR.

The daily model, SJRIODAY contains the following tributary river segments:

- Five miles of the Merced River below USGS gaging station near Stevinson.
- Fifteen miles of the Tuolumne River below the USGS gaging station at Modesto.
- Nine miles of the Stanislaus River below the DWR gaging station near Ripon.
- Six miles of Salt Slough below the USGS gaging station near Stevinson.
- Nine miles of Mud Slough below the USGS gaging station near Gustine.
- Several miles of three west side tributaries: Del Puerto, Orestimba and Hospital / Ingram Creeks.

Daily flow calculations for the SJRIODAY model are made using hydrologic routing techniques. Water quality constituents are considered conservative. This data is used to establish initial conditions for model runs and to generate a two-week forecast of flow and EC. In the absence of real time data, boron and selenium forecasts are made using the most recently available data combined with historical means and the best judgement of the modeler. Real time or forecasted rainfall can be used to account for additional runoff in the basin. Real time data is supplemented by mean monthly flow and water quality data for other model components for which no real time data is available including: groundwater, riparian and appropriative diversions, surface and subsurface agricultural return flows, riparian evapotranspiration, evaporation and precipitation. These components are estimated within the model based on seasonal variability and water year classification provided by the modeler.

## GRAPHICAL USER INTERFACE (GUI)

A GUI was designed for the SJRIODAY model to be user friendly, using the point and click capability of the Windows system (Figure 4). Upon executing the GUI a colorful map of the San Joaquin River system is displayed on the computer screen. The user can direct the arrow cursor to any part of the map on the computer screen, and, using the point and click system available within Windows, recall the data for review or for changes of input conditions. The user can also scroll through a display of dates, viewing the temporal variations of water quality parameters at any map location on the screen and can display spatial color coded changes in water quality at any given time. By clicking at a time advance button, the user can create a near-animation of how a slug of poor quality water moves through San Joaquin River.

The GUI will performs five functions:

1) collects real-time monitoring data for initial conditions
2) edits and uploads water operators' operational schedules
3) runs the predictive SJRIODAY model
4) downloads model results
5) displays the results

There are two versions of the GUI. The general version for water operators has the capabilities to edit and upload operational schedules of reservoir releases, to download the results of computer runs using the forecasting model, and to display the output from these runs. This version does not allow the user to make a full model run. The full version of the GUI has the same capabilities as the operators' version but also allows the user to download monitoring data and to run the forecasting model SJRIODAY.

## DATA REQUIREMENTS FOR FORECASTING MODEL

The forecasting model performs best when provided with schedules of future operations, either of drainage discharges or east-side reservoir releases. These deterministic inputs reduce the error band associated with the inherent stochastic nature of river flows and agricultural loads. Hence to both make reliable forecasts and be able to act upon these forecasts by increasing or reducing the mass loading of contaminants to the San Joaquin River coordinated management of these control systems are required. East side reservoirs

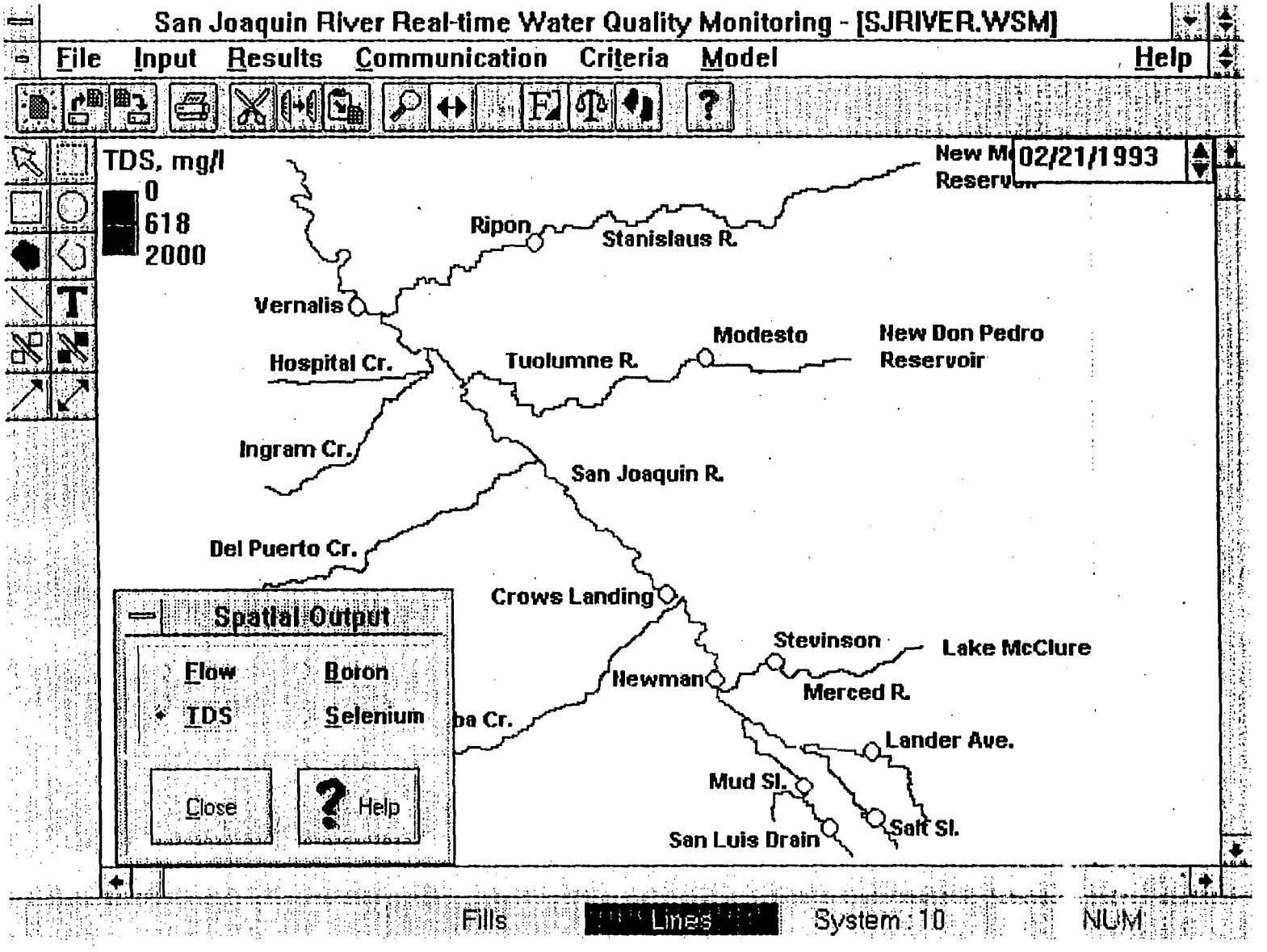


Figure 4. Graphical user interface for the SJRIODAY forecasting model.

provide the control of the east side diluting flows, however these flows are not well coordinated, being made primarily for power generation and irrigation water supply. On the west side agricultural drainage is mostly unregulated by control facilities once it leaves the tile sump, although most water districts have constructed facilities to pump combined drainage return flows at the district outlet for blending purposes with fresh water.

## MODEL RESULTS AND FORECASTS

Forecasts of flow and water quality at Vernalis have been made each week since November 1995 and a post audit of forecast accuracy has been broadcast on the electronic listserver, comparing the forecasts with observations obtained from CDEC and the real-time monitoring system. Figures 5 - 10 show the performance of the forecasting model for predicting flow and TDS at Vernalis. The observed CDEC and model simulated flows at Vernalis and the observed CDEC and simulated TDS concentrations and assimilative capacities are in closer agreement in the case of the 1 week forecast than for the 2 week forecast, as might be expected. The model performed well during most of 1996 and, in particular, the summer months, when flows and water quality on the San Joaquin River were dominated by agricultural drainage from Mud and Salt Sloughs (Figures 5-7). In general, the model tends to overestimate flow as well as EC.

Between December 25, 1996 and January 25, 1997 the San Joaquin Valley was subjected to severe winter storms which produced an extraordinary volume of runoff from the east-side Sierran watersheds. Figures 6 and 7 illustrate the problems encountered in making accurate flow forecasts during this period. Without an accurate watershed model runoff forecasts were based on estimates of the flood hydrograph from each contributing watershed and real-time flow data. Although both model and forecast flows continued to overestimate real-time flows between January 14 and January 25, 1997 levee breaks along the San Joaquin River diverted considerable flood flow and probably accounted for much of the discrepancy. The dominance of east-side tributary flows on San Joaquin River water quality during this period made the EC somewhat easier to predict with accuracy. Model and forecast EC are not significantly different from the real time EC data (Figures 8-10).

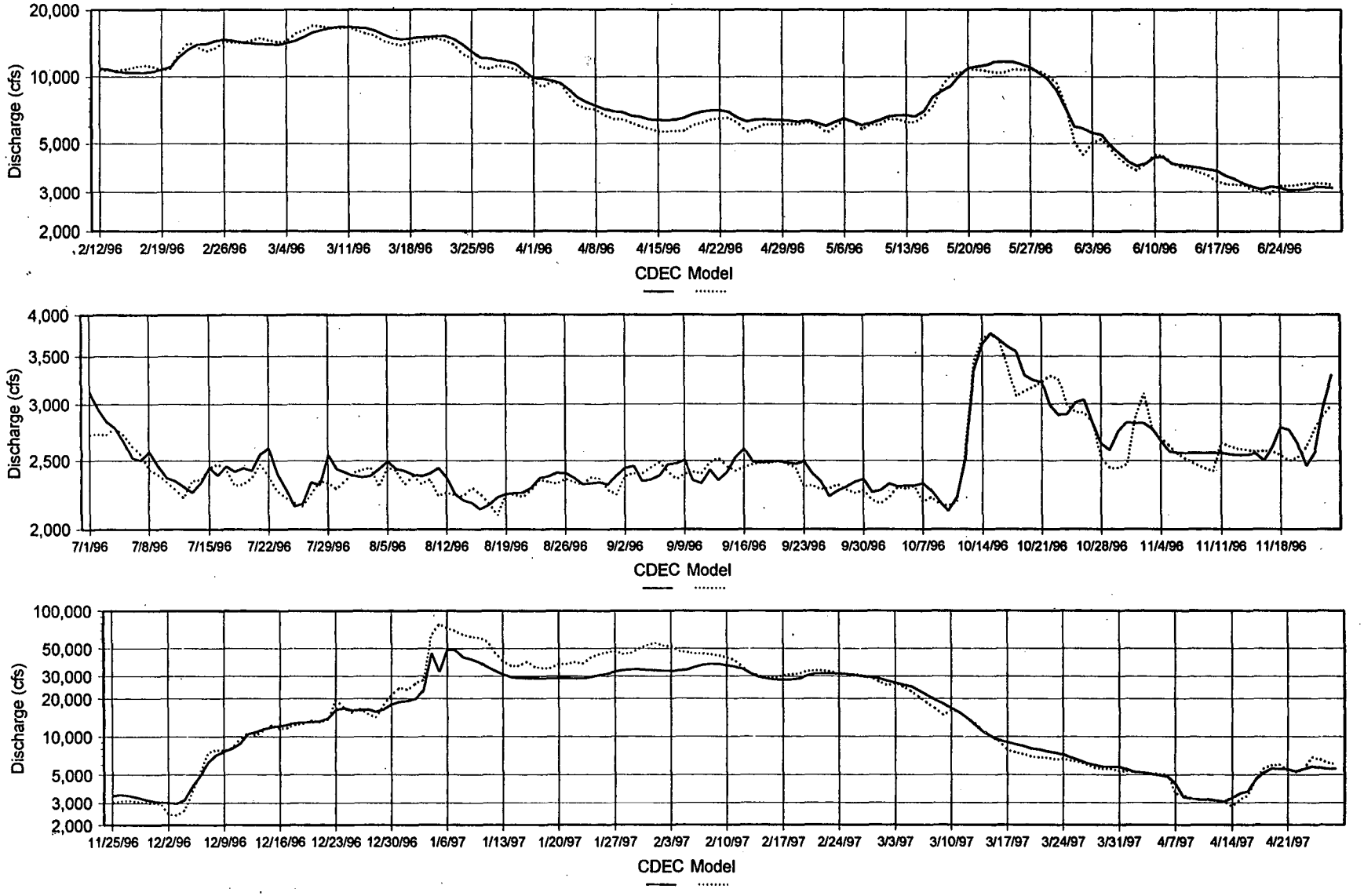


Figure 5. Comparison of observed Vernalis discharge (CDEC) with modeled discharge using real-time data as input.

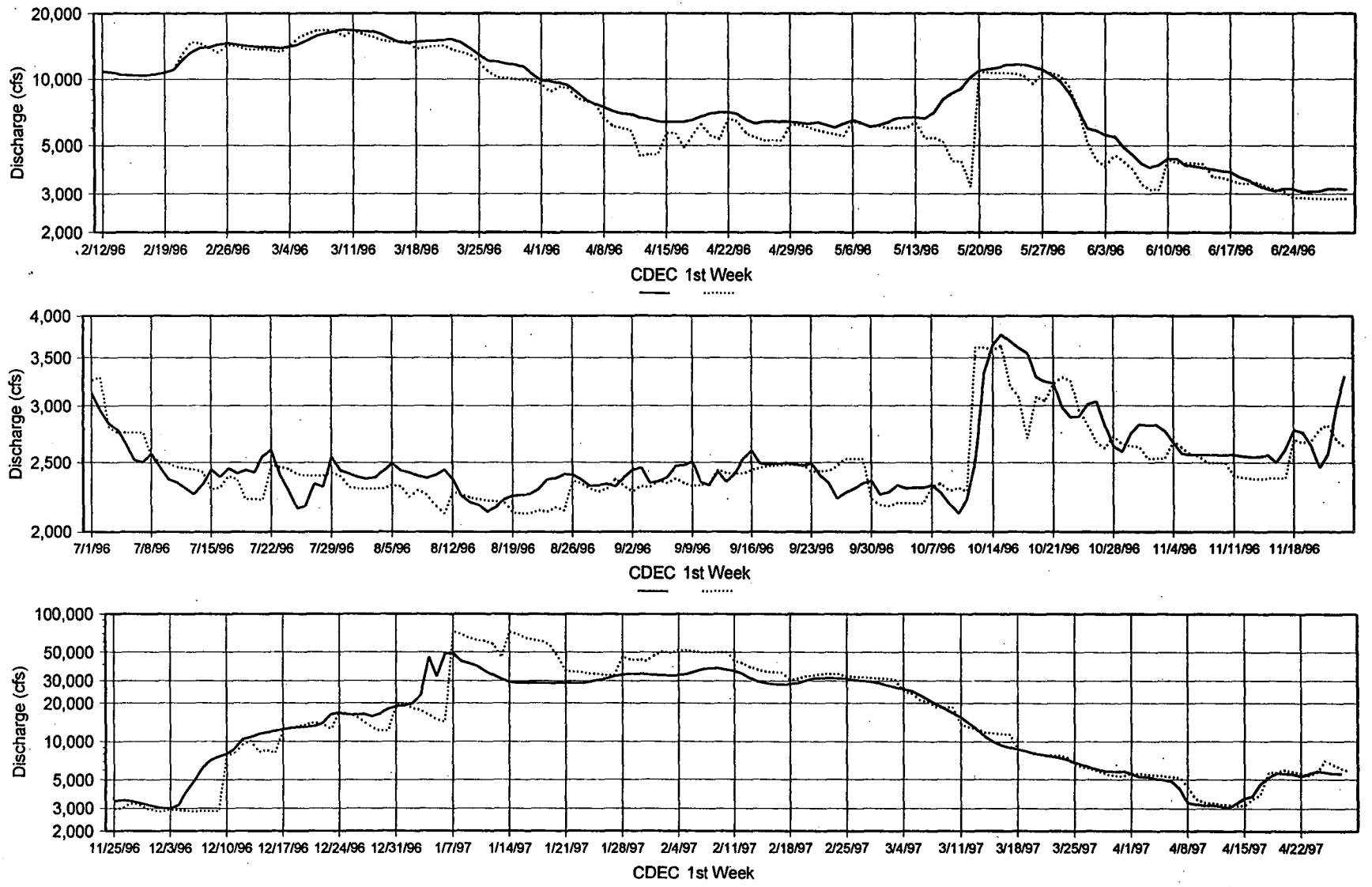


Figure 6. Comparison of observed Vernalis discharge (CDEC) with modeled discharge using first week forecast as input.

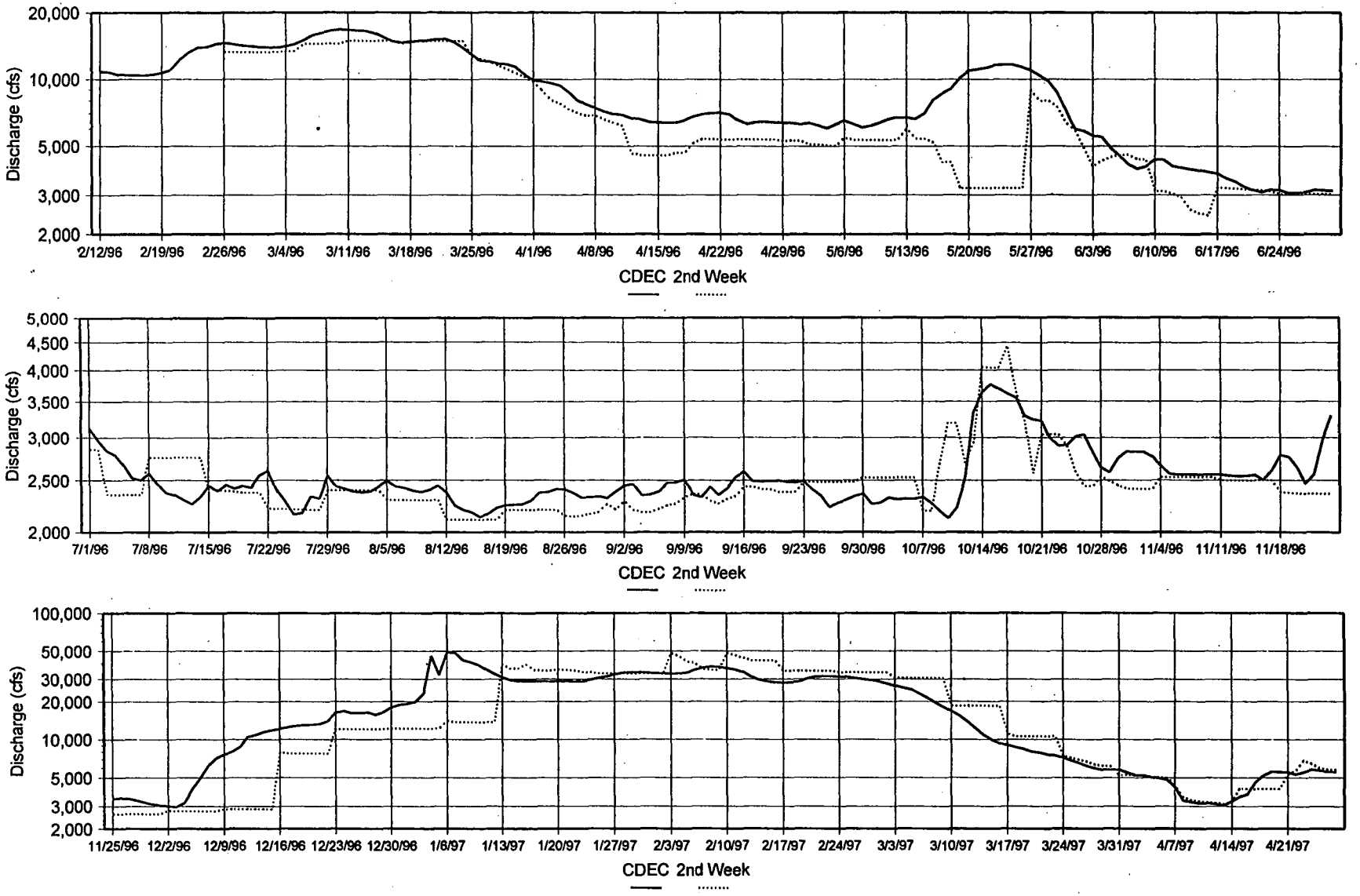


Figure 7. Comparison of observed Vernalis discharge (CDEC) with modeled discharge using second week forecast as input.

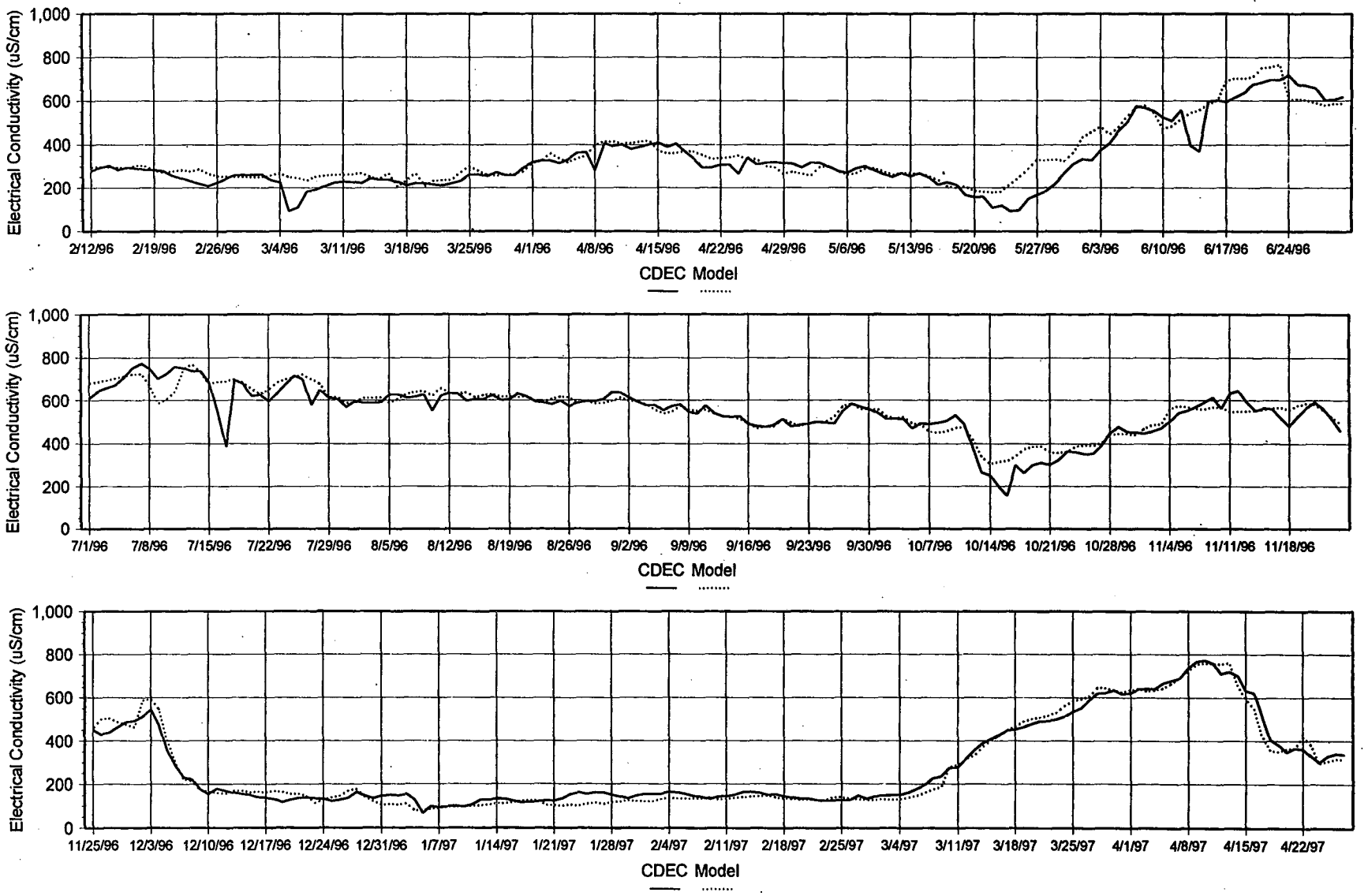


Figure 8. Comparison of observed Vernalis EC (CDEC) with modeled discharge using real-time EC data as input.

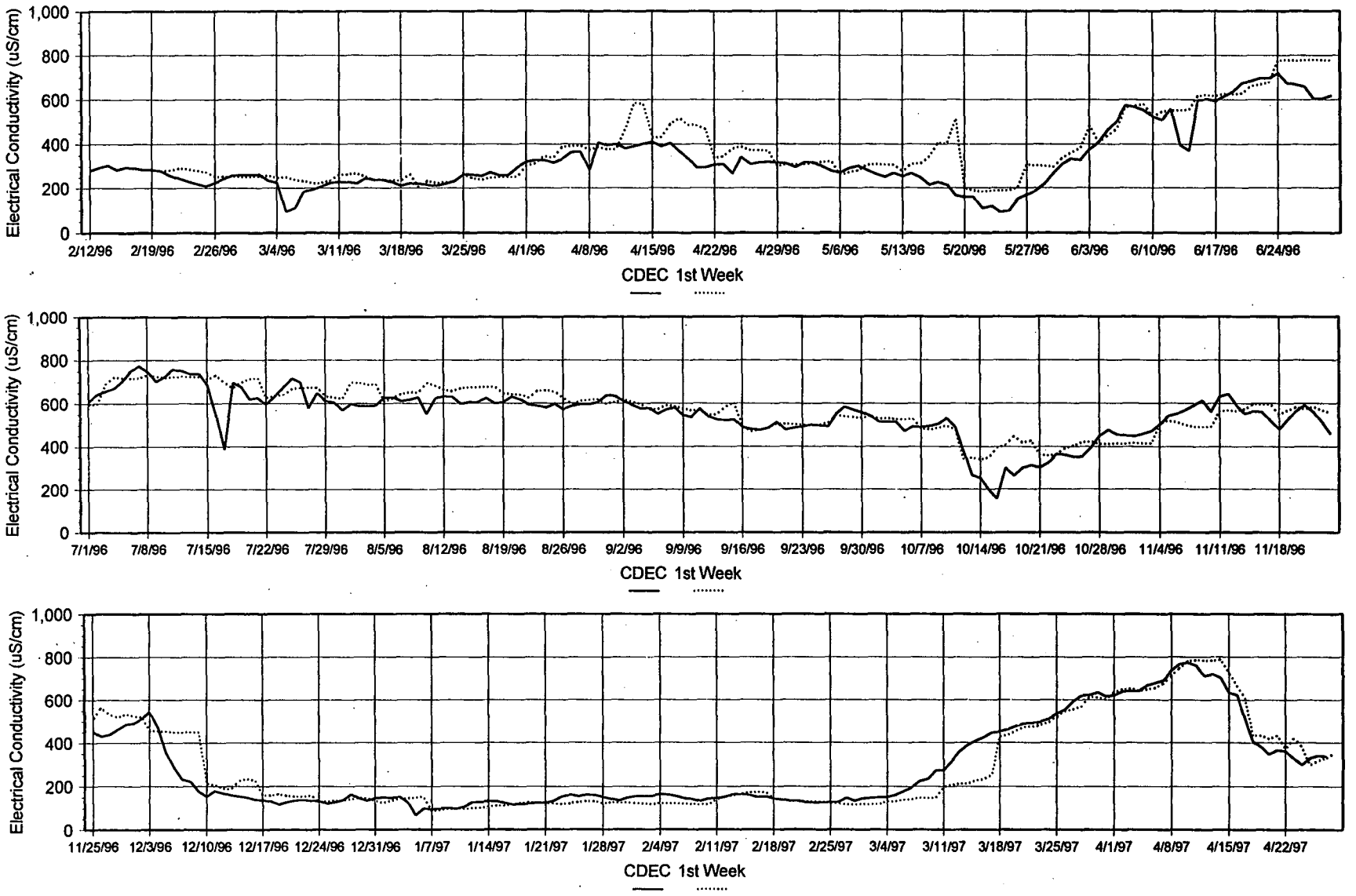


Figure 9. Comparison of observed Vernalis EC (CDEC) with modeled discharge using first week forecast EC as input.

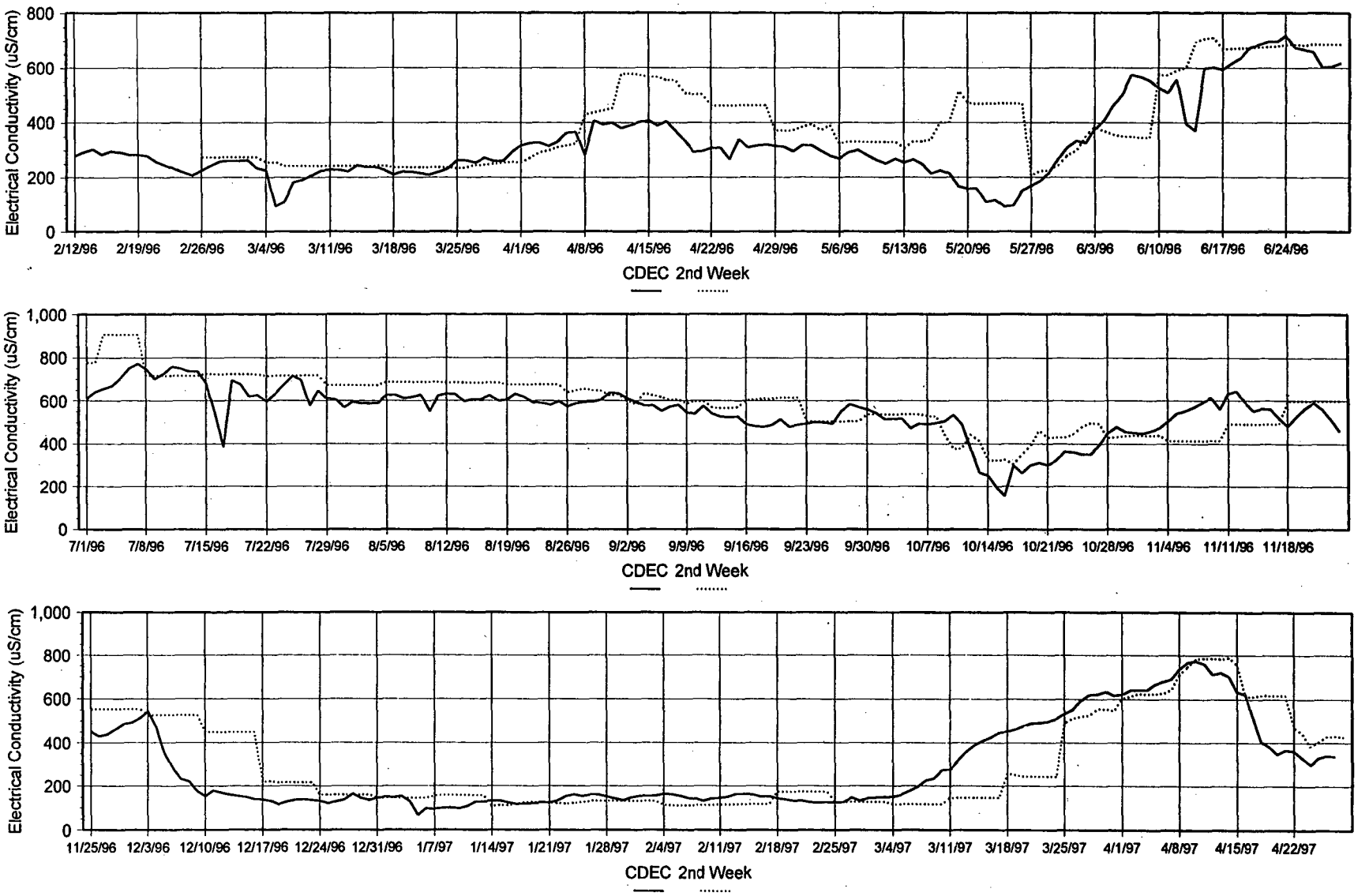


Figure 10. Comparison of observed Vernalis EC (CDEC) with modeled discharge using second week forecast EC as input.

## CASE STUDY

During early January 1996 the Grassland Water District, with the recent acquisition of supplemental water supplies under the Central Valley Project Improvement Act, sought to make an early drainage release of ponded water to reduce the likelihood of downstream salinity impacts and salinity objective violations in the San Joaquin River later in the season. The Water District requested that the authors provide a forecast of the most advantageous time to make this release. A model forecast, made on January 15, 1996 suggested that the combination of high river flows and an imminent rainstorm might provide the necessary assimilative capacity. The peak wetland release was timed so that it would coincide with the peak flow in the San Joaquin River. Wetland flushing began on January 18 and ended on February 19, with the peak flow occurring between January 27 and February 10. This peak flow arrived at Vernalis between February 1 and February 14 (Figure 11). On January 15, before the arrival of the wetland releases, flow at Vernalis was approximately 2000 cfs and the EC was 1000 uS/cm. At the time of arrival of the peak wetland releases at Vernalis, flow at Vernalis ranged from 5,300 to 10,500 cfs and the EC ranged from 220 to 430 uS/cm. Assimilative capacity was positive in the River throughout the simulation period owing to the rainfall-runoff events in the upper watershed. No violations of the EC objective occurred during the trial period and there were no EC violations in the San Joaquin River during March and April, 1996.

## WATER QUALITY MANAGEMENT AND CONTROL FACILITIES FOR AGRICULTURAL DRAINAGE

The screening models, discussed previously, assumed some type of dynamic control over the discharge of subsurface drainage in order to take advantage of actual assimilative capacity of the San Joaquin River and did not consider the reoperation of east-side reservoirs. The most cost-effective control structures for a real-time system would allow for the storage of excess effluent during periods of low assimilative capacity and the discharge of greater amounts of effluent during periods of high assimilative capacity. Currently, dynamic control of drainage can only be achieved in one of two ways - recirculation of drainage water and manipulation of subsurface drainage sumps. These techniques result in the storage of contaminants in the vadose

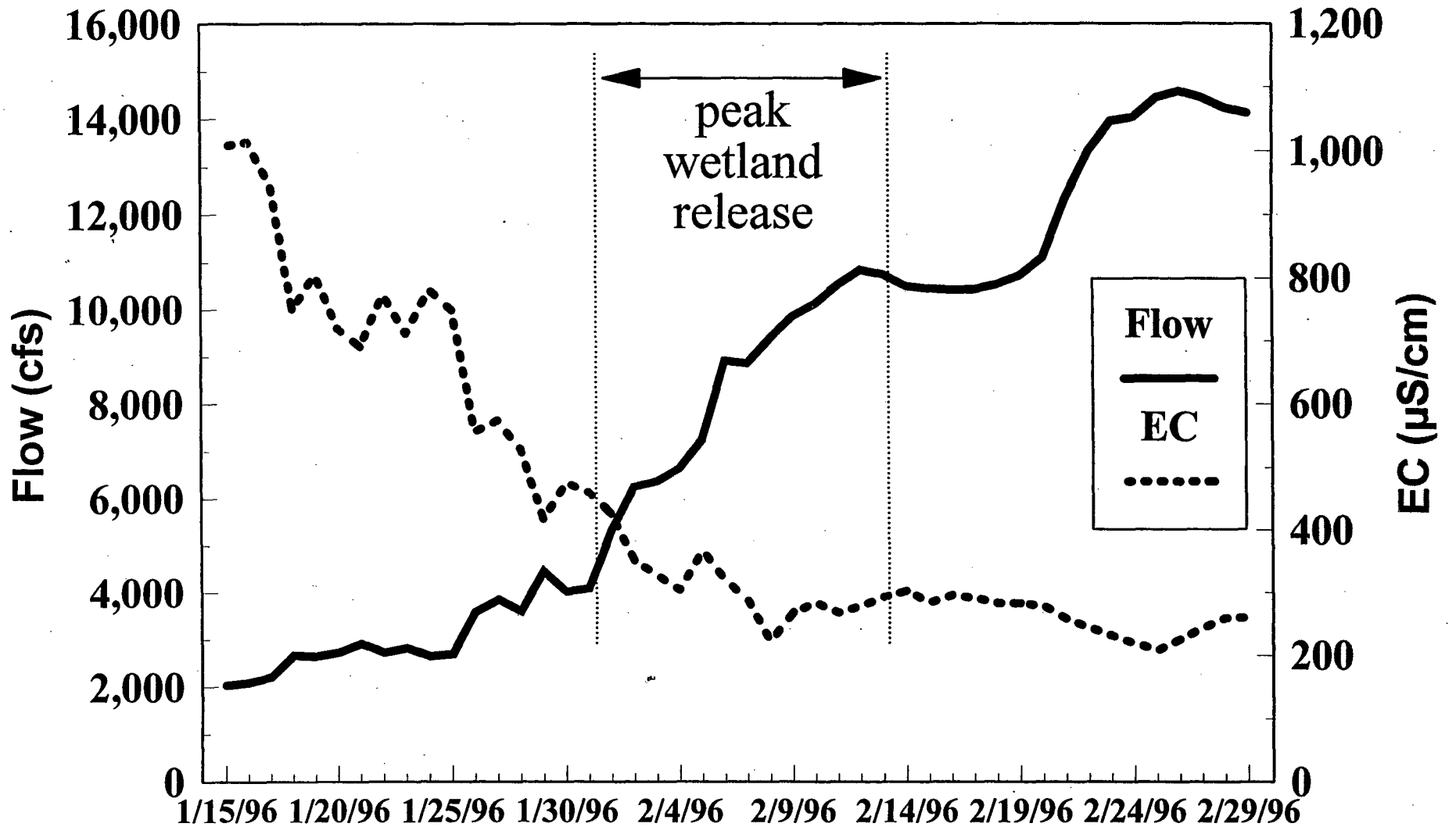


Figure 11. Flow and EC in the San Joaquin River at Vernalis resulting from the scheduled wetland release during the study period.

zone and can be effective in minimizing discharge during periods of low assimilative capacity.

The amount of recirculation that can take place will be limited by the tolerance of the crop to salt and boron. Generally, when drainage is recycled it is blended with good quality surface supplies to minimize the salt and boron impacts on the crop. The disadvantage to this control technique is that the dissolved solids must then be leached out of the crop root zone. A series of irrigation events may be required to fully leach out the dissolved salts, therefore, an extended period of high assimilative capacity is required to discharge the stored contaminants. In addition, a greater amount of good quality supply water may be needed in an irrigation system that includes recycled subsurface drainage than in an irrigation system that uses just good quality supply water (Rhoades,1984).

Another available option for dynamic control of subsurface drainage is the manipulation of drainage sump pumps. These pumps turn on when the water level in the sump has reached a certain level. The pumps could be shut off during periods of low assimilative capacity and turned on only when assimilative capacity became available. The disadvantage to this option is that the primary function of the sump and tile drainage system is to prevent the root zone from being waterlogged by rising groundwater. After the sump is shut off the ground water level will soon rise and depending on shallow aquifer characteristics and the irrigation practices of the grower and his nearest neighbors, may rise to a point where harm to the crop will occur.

The manipulation of sump pumps has limited utility during periods of available assimilative capacity - fall, winter, and "wet" water years. During the fall and winter, the non-irrigation season, water table levels generally decrease. Since the sump pumps are relatively shallow, typically between 8 and 12 feet below the land surface, turning on the sump pump would yield little discharge. During wet water years, discharge from the sump pumps combined with surface water runoff often fills drainage canals to capacity. Therefore, little opportunity for further discharge exists.

Both of these control options have limited utility with respect to responding to short term opportunities for discharge because of the time lag and long response time between the discharge of pollutants from the sump and the transport of the discharge to the San Joaquin River.

A means of reducing the response time is to build regulating reservoirs. During periods of low assimilative capacity, excess drainage could be stored in the reservoir and later released when assimilative capacity became

available. If the reservoirs were located near the San Joaquin River, there would be less reliance on model forecasting to determine allowable discharge levels and greater opportunity to take advantage of short-term discharge opportunities.

The experience at Kesterson Reservoir (Presser, 1994) and in the evaporation ponds of the Tulare Basin, California (Skorupa and Ohlendorf, 1991) has shown the potential danger of holding large volumes of selenium contaminated water above ground for extended periods of time. In both cases, bioaccumulation resulted in observable impacts to wildlife, even at low water column concentrations. Regulating reservoirs could be designed to lessen their attraction to wildlife by constructing deep reservoirs with steep, un-vegetated shorelines. A hazing program and provision of alternative habitat could also minimize wildlife impacts. In order to minimize land requirements for regulating reservoirs and mitigation habitat and to minimize threats to wildlife, drainage load reductions would be required if above ground regulating reservoirs are to be used to control discharges.

## REOPERATION OF EAST-SIDE RESERVOIRS FOR WATER QUALITY MANAGEMENT

East-side reservoirs are operated for power and provide irrigation water supply to east side agricultural water districts and municipal water to cities and towns located along the major tributaries to the San Joaquin River. The reservoir operators are obligated to make releases to aid fish migration during certain times of the year as part of their FERC licences and for other purposes as negotiated with local interests. The US Bureau of Reclamation is currently working with certain east-side water districts to compensate districts for additional scheduled releases that exceed normal operations. Although there is no prospect for making east-side releases completely predictable, with operators bound by to follow their forecast release schedules and requiring disclosure and dissemination of these schedules, an advance will have been made towards better water quality forecasting on the main stem of the San Joaquin River.

## INSTITUTIONAL FRAMEWORK

In order for the real-time water quality management system to be fully

implemented and successfully utilized by stakeholders some institution building and policy reform at the State level will likely be required. Incentives need to be created for all parties for the acquisition, use and sharing of data and operational schedules created with or without use of the data. Developing mechanisms for dissemination of current information to interested parties is the first step and has been initiated through use of the internet and the creation of a listserver for the project. The listserver automatically relays messages including real-time flow and water quality data, water quality forecasts, and scheduled reservoir releases for downstream fisheries, flood control and recreation from the originator of the information to the entire subscriber list. The fact that not one of the 60 subscribers to the listserver have unsubscribed provides some indication that the information relayed is somewhat useful. A number of workshops have been conducted throughout the San Joaquin River basin to explain the use of the GUI and the steps required to download and view daily forecast data.

A problem is created in this unstructured sharing of information in that it does not have a formal feedback loop - hence actions taken as a result of the information gleaned from the listserver is not accounted for in the current system. One means of dealing with this problem would be to set up specific schedules for issuing San Joaquin River water quality forecasts and for issuing official updates to these forecasts based on feedback information. To do this effectively will require the establishment of a central authority with coordination responsibility for operations and actions that affect water quality on the San Joaquin River.

The current system has been in place for less than 2 years. It is envisaged that the technology transfer process and the loosening of institutional constraints will take several more years before the potential benefits of this system are realized.

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